Shadow Mode Assessment Using Realistic Technologies for the National Airspace System (SMART NAS)

ATTACHMENT 1 – STATEMENT OF WORK

INTRODUCTION

Background

The current National Airspace System (NAS) is a complex, efficient, and safe system. Current modernization of the NAS is based on evolutionary changes; only one or two major system or technology upgrades are introduced at a time to ensure seamless integration and transition.

NASA and the FAA are developing new concepts and technologies to address the needs of the Next Generation (NextGen) Air Transportation System. NextGen Air Traffic Management (ATM) will increase the capacity of airspace, reduce delays, and reduce the cost of ATM operations. Improving the performance of air transportation system by reducing delays, and increasing airspace capacity and airport throughput is a national need. One of NASA's goals is to accelerate transformation of the NAS by developing concepts and technologies to improve NAS performance.

Various pressures affect the number of technology introductions; however, there are significant technical risks of inserting multiple technologies simultaneously, because the combined integrated impact of future concepts and technologies cannot be fully anticipated with current state-of-the-art modeling and simulation capabilities. Therefore, the process of technology insertions (other than budgetary limitations) remains a serial, one-at-a-time approach, which results in to slower transformation of the NAS. This slow pace towards NextGen and beyond has been a source of frustration for the airspace user community and other stakeholders that have recommended NextGen acceleration. Currently, there is no capability that allows testing and validating of advanced concepts, algorithms, human-automation, air-ground allocations/architectures and associated technologies and their interactions at the entire NAS level using real, operational data.

In order to accelerate NextGen, multiple technologies need to be simultaneously inserted into the NAS. Multiple technology insertion is only possible if integrated testing and validation of NAS-wide operations are conducted to ensure the benefits and feasibility of concepts and technologies. Such integrated assessments, testing and validation will provide the necessary data and confidence that proposed concepts, algorithms, technologies, and human-automation and air-ground allocation/architectures are mature, feasible, reliable, inter-operable, and beneficial.

NASA has a need to develop Shadow Mode Assessment using Realistic Technologies for the NAS (SMART NAS) capability to accelerate transformation of the NAS. Towards that end, NASA has a need for identifying detailed design architectures to enable SMART NAS. This capability will allow integrated, real-time and/or fast-time assessment of gate-to-gate operations and their performance using real-world NAS inputs. SMART NAS would allow for plug-and-play of different technologies to operate in combined real, virtual, and constructive manners as dictated by the study goals.

Ultimately, the SMART NAS capability will be developed and implemented by NASA's Airspace Systems Program of the Aeronautics Research Mission Directorate and will support the goal of accelerating the transformation of the NAS. The first step towards such development is to identify possible architectures, complete a benefits assessment and cost estimation. It is likely that development and implementation of the selected architecture will be done in-house, by civil servants with support from on-site contractors.

SCOPE OF WORK

Each of the selected contractors shall perform the following functional elements:

- Identify and develop open architecture alternatives for a SMART NAS capability. The simulation architecture itself will be open and the approach for the software functionality portions of the architecture will adhere to open source principles.
- Document and present proposed SMART NAS design architecture concept studies in sufficient detail to enable evaluation by NASA.
- Conduct a benefits assessment of the SMART NAS capability.
- Develop an initial cost estimate for capability development as well as maintenance.
- Identify logical steps to develop an operational SMART NAS capability.

SMART NAS GOALS

The goal of the SMART NAS is to develop a capability to explore alternative concepts, algorithms, technologies, and human-automation and air/ground allocations/architectures at the NAS level in an integrated manner. SMART NAS will enable assessments to demonstrate feasibility and benefits for modernization-related decision-making.

Specifically, the objectives of SMART NAS are to:

- Develop a capability to test ATM concepts, algorithms, technologies, and human-automation and air-ground allocations for NextGen and beyond in an integrated fashion to accelerate transformation decisions related to the NAS. This concept will enable fast time as well as real time analysis at the gate-to-gate level.
- Reduce the time to test concepts, technologies, and their interactions, interoperability, and integration.
- Provide an open architecture plug-and-play capability to compare alternative technical approaches for the same concepts or different concepts and/or human-automation and air-ground allocations/architectures to address an identified operational challenge.
- Understand interactions among various concepts, algorithms, human-automation and air-ground allocations/architectures, and technologies to identify benefits and feasibility at the NAS level.
- Examine robustness, reliability, resilience, interoperability and stability of concepts, algorithms, human-automation and air-ground architectures, and technologies as compared to current NAS operations.
- Provide a real-time assessment of concepts, algorithms, human-automation and air-ground architectures, and technologies to compare with current NAS operations.
- Assess large-scale contingency operations alternatives using shadow-mode simulation by conducting emergency drills (e.g., a day without space-based assets).
- Examine a variety of safety cases to assess robustness of the concepts and technologies.
- Examine alternative air and ground architectures for ATM to identify the highest performing and cost effective alternatives. The assessments will consider a range of functional allocations and their implications (e.g., latency) on NAS performance metrics such as but not limited to capacity, throughput, delays, efficiency, and total costs.
- Enable uncertainty assessment of all outcomes obtained as a result of SMART NAS operations.

CHARACTERISTICS OF THE SMART NAS CAPABILITY

In order to transform the entire NAS, proposed functions need to be demonstrated in an integrated fashion so as to gain confidence in the entire system. Therefore, a shadow-mode NAS will be developed that takes a one-way feed from the NAS and its inputs (e.g., weather, flight plans, airport arrival rates, system constraints, etc.), but runs the entire system (or parts of it) using proposed concepts, air-ground architectures, and technologies in order to demonstrate their performance and to validate that the assembled technologies work seamlessly. The SMART NAS capability will be required to run 24 hours a day, 7 days a week operations for a period of time (depending on the concepts, it could be hours, days, months, or longer) to demonstrate benefits, stability, and other performance indicators. Once confidence is gained that planned concepts and technologies are well developed and demonstrate benefits and/or desired performance, functional requirements will be generated. This process will continue as the concepts and technologies evolve with time, traffic, and vehicle types.

SMART NAS has two main uses:

1. Examine new and advanced concepts and technologies in an integrated fashion with real, virtual, and constructive data and constraints, and

2. Conduct "what-if" analysis for current operations using real-time decision making to ensure the most efficient NAS-wide operations.

The first applications are more for researchers, decision makers, air-ground architecture developers, software/hardware engineers, system integrators, and organizations that are developing new technologies and want to ensure their seamless integration with other technologies that support NAS-level gate-to-gate operations. When it is developed and matured, SMART NAS is expected to be an ATM community resource, similar to Numerical Propulsion System Simulation (NPSS).

SMART NAS is being planned to model new architectures allowing greater use of autonomy, trajectory-based operations, and new and different roles for both humans and computers. It will be open architecture, providing access for partners and stakeholders to contribute concepts and methods. Importantly, it will be configured to accept today's operational inputs such as but not limited to flight schedule, demand, airport capacities, environmental constraints (e.g., weather), and fly today's schedule in tomorrow's NAS. This operational capability will be important to evaluate performance of the new architecture and procedures as compared to the way the system actually flew. This will generate a stronger business case for transformation and provide insights into unknown interactions and safety considerations.

The second use is more for real-time NAS operators and service providers who want to simultaneously consider all NAS-wide constraints and assets to generate the most efficient NAS-wide plan and update it as necessary throughout the operation.

The main features of SMART NAS are as follows:

- Shall allow alternative NAS-level architecture comparisons that include different air/ground allocation schemes to enable trajectory-based operations and roles and allocations for flight deck, air traffic controller/traffic manager, dispatchers, and third-party fee-for-service applications to the NAS. The comparisons shall produce NAS-level as well as individual aircraft level performance metrics.

- Shall be capable of operating continuously, 24 hours per day, 7 days a week, for an extended duration (e.g., months).

- Shall be capable of simulating domestic and international traffic.

- Shall offer a plug-and-play capability for researchers and organizations inside and outside NASA to examine the feasibility and benefits of the proposed, new concepts and technologies at a NAS-wide scale, in an integrated fashion, using real-life data sources that are not possible with current capabilities.

- Shall allow simulation and modeling of trajectory-based operations using live, constructive, and virtual environments.
- Shall allow existing real-world automation systems to be included using interfaces operated by the FAA, airlines, and airports within the plug-and-play SMART NAS capability (e.g., existing arrival metering or conflict detection tools). This refers to integrating disparate real-time software systems, not simply models of those systems.
- Shall be capable of connecting and/or integrating with new and pre-existing NASA models and capabilities developed to simulate the NAS or parts of NAS operations.
- Shall be capable of integration with human-in-the-loop capabilities. The components that are not human-in-the-loop will be model driven, but will interact with human-in-the-loop portions.
- Shall be capable of real/live, virtual, constructive, and hybrid-mode operations to simultaneously operate in real/live and virtual traffic.
- Shall be capable of generating real-time (and predicting) performance metrics at NAS wide and individual aircraft levels. These metrics shall include, but not limited to, delays, capacities, throughput, fuel efficiency, track miles, buffers, arrival/departure rates, flight costs, environmental impact, cost of operating the NAS by the service providers, and cost of operating in the NAS by the airspace user, etc.
- Shall be able to run multiple parallel "NAS universes" representing different combinations of concepts, algorithms, air-ground architectures, and technologies for comparison of alternatives related to concepts, technologies, procedures, and architectures and their confluence and their NAS-wide performance with each other and with current operations.
- SMART NAS shall be capable of running in fast time as well as real time modes. It shall be capable of developing and conducting "what-if" analysis to generate the most efficient, real-time operational concepts.
- Shall be capable of recording, replaying, visualizing, and re-running scenarios and comparisons.
- Shall be capable of accepting direct, one-way inputs continuously that are also received by the NAS.
- Shall be capable of perturbing inputs using stochastic models.
- Shall be capable of conducting operations from multiple sources in a distributed manner.
- Shall be capable of examining a variety of safety cases to assess robustness of the concepts and technologies, and their interactions.
- Shall be capable of representing and examining alternative architectures for ATM to identify highest performing and cost effective alternatives.
- Shall be capable of assessing uncertainty in performance measures obtained as a result of experiments.
- Shall be developed using non-proprietary commercial or open source software.

SMART NAS inputs will include but are not limited to airport and airspace data, weather data, traffic and Official Airline Guide data. The outputs will include performance metrics. The heart of the capability is the modeling of major air, ground, and Airline Operations Center (AOC) functions. These functions can occur in a singular or combined live/real, virtual, and constructive environment. Further, SMART NAS capability and supporting open architecture(s) should also allow examination of future operations with advanced human-machine and air/ground allocations including autonomy, self-governance, self-configuration, self-optimization, self-protection, and self-healing. It should allow inputs from different sensors, provide dynamic sensor fusion capability, and allow examination of redundant human-machine and air/ground functional architectures.

Live systems are where real people operate real systems. Virtual systems are where real people operate simulated systems. Constructive systems involve simulated people operating simulated systems. Real people stimulate (provide input to) constructive system simulations, but are not involved in determining the outcomes. As a number of functions across the NAS need to be processed simultaneously for SMART NAS, it is anticipated that such processing would be computing intensive. Therefore, options such as supercomputing, cluster computing, cloud computing, and networking would be created to support SMART NAS studies.

The SMART NAS, once developed, is envisioned to be an air traffic management (ATM) community resource that will offer opportunity for integrated assessments based upon real-time, operational data simulations. To enable its wider community use, external licensing should not limit any usage for dependencies related to simulation framework/architecture, simulation infrastructure; data recording/collection, simulation command/control, visualization, and related architecture; simulation communication architecture, or any other simulation specific capabilities. Therefore, to enable such widespread use, the architecture shall allow extensibility by being open, and where the approach to the software functionality in the simulation architecture adheres to open source principles. The architecture will enable plug-and-play capability for ATM algorithms and/or technologies from various organizations. It is possible that these ATM technologies and algorithms (ATM concept specific algorithm/technologies that will be tested using the open SMART NAS architecture, such as a surface operations scheduler, but not one simulation specific), might be proprietary or open–source. However, both NASA and the ATM community will benefit from an open SMART NAS architecture that includes an open source software simulation framework that will provide the ability to maintain and modify the code and extend the scope at will.

The Government requires unlimited rights or broad licenses to use and release the concepts and design ideas developed and delivered under each contract awarded for this effort. Software functionality must to adhere to open source principles, which will enable full implementation and unencumbered future enhancement of the SMART NAS capability. As noted above, in the unlikely event of a follow-on procurement of the system build, that procurement activity will be completely separate from this procurement action.

<u>DESCRIPTION OF TASKS AND DELIVERABLES</u>

Task 1: Work plan development

Task 1 is to develop the work plan. This task shall include formulation of goals, technical approach, schedule, resources, risk, management plan, cost, methods to track progress, and review of relevant ATM tools and how they can be used or extended for this effort. The first deliverable is a description of work plan development process (in a Microsoft word or power point format). A Kick-Off Meeting will be held at NASA Ames Research Center to review the proposed work plan development process and initial progress.

Detailed contractor work plan

The second deliverable shall be a detailed work plan (in a Microsoft word format) that describes the goals, technical approach, schedule, resources, risks, management plan, and technical progress tracking. The contractor shall also conduct and report a thorough review of available capabilities; identify gaps in current ATM gate-to-gate NAS wide simulation and modeling capabilities; identify similar large-scale live, virtual, and constructive simulation and modeling capabilities, their lessons learned, and their applicable technologies to integrate legacy and new systems/models; and identify technology gaps (if any). The contractor shall describe the approach for architecture development, and cost and benefits assessments. The contractor shall describe the work plan to complete tasks 2 and 3.

Task 2: Develop Architecture Alternatives for SMART NAS
Task 2 will focus on the design architecture concept study and identification of alternative architectures for future development of the SMART NAS.

Develop Architecture Alternatives for SMART NAS and their detailed descriptions
The fifth, tenth and eleventh deliverables (delivered in electronic and paper format both) shall focus on developing detailed descriptions of functional data, hardware (as applicable), and integration and software architectural alternatives for SMART NAS. The descriptions shall include, but are not limited to comprehensive ATM functions/services to represent the NAS, open architecture alternatives, software language and operating systems, integration requirements, plug-and-play capabilities where different algorithms and technologies can be easily integrated and/or swapped for assessments, input and output needs, network protocols, computing platform alternatives and their descriptions, data collection and recording capabilities, visualization capability, and command and control structures to plan, conduct and monitor NAS-wide distributed simulations. These will include the entire NAS-level ATM, and flight deck, Airline Operations Center (AOC) agents for gate-to-gate operations. A proposed methodology to validate SMART NAS and detailed specification of performance metrics shall also be described.

Particular attention shall be paid to the specification of modularity and flexibility of the design and constructions of interfaces among the components of the system. Descriptions shall contain sufficient detail to enable evaluation of realism.

The contractor shall describe a process for developing and modeling NAS architectures in the context of SMART NAS and provide some analysis of the range of future alternative air-ground NAS architectures that can be anticipated and how well their SMART NAS architectures can handle them. The contractor shall discuss links, application protocol interfaces, and access to all data streams for data mining purposes in order to assist in the development of data mining tools to enable the detection of precursors to aviation safety events.

The contractor shall address all characteristics of SMART NAS (listed in the section titled "Characteristics of the SMART NAS Capability") and develop open architecture concepts to support these required functionalities. The contractor shall identify open architecture alternatives for SMART NAS based on standard architectural views of a system, especially the functional, structural, concurrency, and data views. Enterprise architectural styles could include, but not be limited to, Zachman Framework, High-Level Architecture, The Open Group Architecture Framework, Department of Defense Architecture Framework, Service-Oriented Architecture, or other innovative architectural design approaches. Their applicability for building the SMART NAS capability shall be carefully assessed and reported in detail.

As part of developing studies and analyses of alternate system design architecture concepts and cost estimates for the SMART NAS, the contractor shall include details of components (i.e., models, simulators, existing capabilities, and proposed systems) that could be included in SMART NAS, and answer the following questions:

- Are the components being recommended appropriate?
- If they are Commercial Off The Shelf (COTS)-based, how well can they be adapted to SMART NAS objectives?
- What are the risks involved?
- What are some prior applications of these components that could be related to SMART NAS objectives?

A clear mapping of SMART NAS functionality to support air traffic control, flight deck, and dispatch operations and associated capabilities shall be discussed and documented. The contractor shall also describe the performance metrics that will be generated and computed from SMART NAS outputs.

The issue of SMART NAS "usability" is important. The process of setting up, configuring, and running SMART NAS is important. The contractor shall address and identify possible SMART NAS user groups, the importance of system usability, and describe in detailed key features that will promote the usability.

SMART NAS also requires the use and integration of specific, heterogeneous data sources (e.g., Official Airline Guide, radar tracks, flight plans, weather data, etc.) for handling both fast-time and real-time modes. The contractor shall identify all data sources that SMART NAS will use and how its architecture will consider those as inputs, and address possible data integration techniques (e.g., Data Warehousing versus Data Federation approaches or a hybrid approach of the two) that could tentatively support SMART NAS.

Validation of SMART NAS at each stage will be critical to establishing its utility and effectiveness. The contractor shall address the issue of SMART NAS validation and how it might be approached as the system architecture is developed.

The contractor shall also provide all models and supporting evidence developed during this effort, documentation of repeatable test and experimental validation capabilities in the final report. The Task 2 product and deliverables should be in such detail so SMART NAS can be developed using that architecture description.

The contractor shall clearly describe and explain how the goals, characteristics, and features of the SMART NAS will be satisfied by the proposed architecture(s). To the extent possible the architecture itself will be open, and the contributors to the functionality in the architecture subscribe to open source principles. The contractor shall describe the understanding of the benefits of open architectures, particularly SMART NAS capability as compared with current ATM simulation and modeling capabilities. These potential benefits include but are not limited to lowering costs, community participation and avoiding vendor lock-in.

The contractor's architecture representation using prototype software should be in such detail that the SMART NAS can be implemented with high degree of confidence in its successful implementation. The contractor shall use methods and tools to represent SMART NAS architecture. The contractor shall also describe software design methods that could be considered for building SMART NAS with rationale for their selection. The contractor shall deliver SMART NAS architecture representation in forms such as but not limited to United Modeling Language, Rational Rose, architectural frameworks, etc. Additionally, the contractor shall deliver any developed a functioning skeletal prototype of the architecture as code

Task 3: Initial cost assessment based on alternative architectures and benefits assessment of SMART NAS

The focus of Task 3 is to conduct a benefits assessment and initial cost assessment for developing SMART NAS based on identified architectures. The benefits assessment shall describe how the SMART NAS is beneficial as compared to other existing modeling and simulation approaches. The contractor shall clearly identify and describe the benefit mechanisms and benefits of developing and using SMART NAS capability. These benefits may include, but are not limited to, identification of unknown interactions, interoperability assessments, reducing the implementation time by early integrated evaluations, integrated benefits assessments and performance comparisons. The contractor shall use and justify the applicable benefits assessment techniques.

The contractor shall use and justify appropriate the cost estimation methods for producing SMART NAS cost estimation. Cost estimation shall include both the development cost and the maintenance costs of implementing/fielding SMART NAS architecture.

A part of the SMART NAS planning effort shall be to demonstrate the value of SMART NAS over existing capabilities. This benefits analysis (time and money savings) shall be conducted. The benefits assessment of SMART NAS will consider but not be limited to its ability to conduct integrated examinations of future concepts and technologies to identify unforeseen interactions; systems engineering related benefits based on identification of risks/problems in the early stages of concepts and technology development; to thoroughly investigate the concepts, technology, and integration considerations using live, constructive, and virtual environments using current and future potential demand profiles, business cases, and scenarios; and to reduce the risk of potential problems in implementation.

Develop cost estimates for each architecture alternative described in the second deliverable and conduct a benefits assessment of SMART NAS capability

The sixth, eighth and ninth deliverables (in word and electronic format) shall include methods, initial costs, and detailed total cost estimate to develop and implement the SMART NAS capability, maintain and operate it for the next 10 years and identify quantifiable benefits of the SMART NAS for the airspace traffic management community at large.

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